PB88-175930

Technical Assistance Document Recommended Recordkeeping Systems for Air Pollution Control Equipment Part 1. Particulate Matter Controls

PEI Associates, Inc., Cincinnati, OH

Prepared for

Environmental Protection Agency, Washington, DC

Aug 87

U.S. Department of Commerce
National Technical Information Service
NTIS

PB88-175930

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Washington DC 20460

EPA 340/1-86-021
August 1987

Stationary Source Compliance Series

EPA

Technical Assistance Document: Recommended Recordkeeping Systems for Air Pollution Control Equipment

Part I — Particulate Matter Controls

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA. 22161

X

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA 340/1-86-021		PB88 175930/AS

4. TITLE AND SUBTITLE
Technical Assistance Document: Recommended Record-keeping Systems for Air Pollution Controls Equipment Part 1- Particulate Matter Control

5. REPORT DATE
August 1987

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Gary Saunders and Ron Hawks

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
PEI Associates
11499 Chester Rd.
Cincinnati, Ohio 45246-0100

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-3963

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Stationary Source Compliance Division
Washington, DC 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
EPA Contact: Kirk Foster, Technical Support Branch, SSCD(MD-7)
Research Triangle Park, NC 27711, Telephone:(919) 541-4571

16. ABSTRACT

This manual discribes the types of records that should be maintained for major particulate matter control systems - multicyclones, fabric filters wet (venturi) scrubbers, and electrostatic precipitators. Records of operating parameters and maintenance activity should be part of any preventive maintenace program. Operating records can also be used to diagnose changes in equipment performance affecting the compliance status of a source. The basic elements of a recordkeeping program discussed in this manual include: control equipment/process operating records, inspection checklist, inspection schedules, inspection reports, and equipment maintenance records. Items to be recorded and tracked for each type of control equipment are listed.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Controls Particulate Control Equipment Operation and Maintenance Recordkeeping Systems		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release unlimited	Unclassified	65
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PC A14.95/A6.95

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA 340/1-86-021

Technical Assistance Document: Recommended Recordkeeping Systems for Air Pollution Control Equipment

Part I — Particulate Matter Controls

by

PEI Associates Inc.
11499 Chester Road
Post Office Box 46100
Cincinnati, Ohio 45246-0100

Contract No. 68-02-3963
Work Assignment No. 112

EPA Project Officer: Louis R. Paley
EPA Work Assignment Manager: Kirk Foster

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Stationary Source Compliance Division
Washington DC 20460

August 1987

DISCLAIMER

This report was prepared for the U.S. Environmental Protection Agency by PEI Associates, Inc., Cincinnati, Ohio, under Contract No. 68-20-3963, Work Assignment No. 112. The contents of this report are reproduced herein as received from the contractor. The opinions, findings, and conclusions expressed are those of the authors and not necessarily of the U.S. Environmental Protection Agency.

CONTENTS

Figures iv
Acknowledgment v

1. Introduction 1

2. Purpose of Recordkeeping 3

Regulatory requirements and recordkeeping 4
Recordkeeping and maintenance programs. 5
Elements of a recordkeeping program 7

3. Multicyclones. 17

Operating records 18
Maintenance records 21

4. Fabric Filters 23

Operating records 24
Maintenance records 30

5. Venturi Scrubbers. 34

Operating records 35
Maintenance records 39

6. Electrostatic Precipitators. 41

Operating records 43
Maintenance records 49
Summary 53

Appendix A. Example work order form 55

FIGURES

Number		Page
1	Example of catalog system used by a large pulp and paper mill	12
2	Bag failure location chart	31

ACKNOWLEDGMENT

This report was prepared for the U.S. Environmental Protection Agency by PEI Associates, Inc., Cincinnati, Ohio. Mr. Louis Paley was the Project Officer and Mr. Kirk Foster was the Work Assignment Manager. Mr. David Dunbar served as the Project Director and Mr. Gary Saunders was the Project Manager. The senior technical advisor was Mr. Ron Hawks. The principal author was Mr. Gary Saunders. PEI Associates, Inc., wishes to thank Mr. Kirk Foster for his guidance and direction on this work assignment.

SECTION 1

INTRODUCTION

One of the many requirements often specified by control agencies for regulated air pollution sources are recordkeeping and reporting of selected operating data, excess emissions, and certain maintenance activities. Many times the recordkeeping and reporting requirements are vague and the specific format of requirements are not specified. This reflects, in part, the site-specific nature of recordkeeping activities and uncertainty associated with knowing what data are useful. As a result, there is a need to establish what minimum data are needed to evaluate the overall performance of a source and correspondingly its compliance status. It is the purpose of this manual to provide minimum recordkeeping considerations for several control equipment categories. The minimum recordkeeping guidelines presented in the manual will contain several "mandatory" parameters that should be monitored along with additional "optional" parameters that may provide useful information. There will, however, still be situations where flexibility is needed with respect to what parameters should be recorded and reported to the air pollution control agency.

Operating parameters and maintenance activity records should be a part of any preventive maintenance program. They should not be an afterthought or just kept to fulfill some legal or regulatory requirements. Good records are an important part of a feedback loop in determining whether preventive maintenance is being performed in a timely manner or if operation and maintenance practices need to be changed. Operating records can also be used to diagnose performance or changes in performance affecting the compliance status of a source that require some action or intervention. Records may also be used to establish representative conditions during stack testing or to establish baseline conditions when changes in operating practices are planned.

The major problems with recordkeeping are deciding what records should be kept, in what format, how often the data should be gathered, and how it

should be analyzed. The amount of paperwork associated with recordkeeping activities can, in some cases, be substantial, which can be a serious drawback to the effective implementation of a recordkeeping and reporting program. There are many approaches to recordkeeping ranging from a simple logbook to computerized work order/spare parts reporting systems. The type of recordkeeping system chosen depends on the type and complexity of the equipment as well as resources available to manage and operate the system.

This manual discusses the types of records that should be maintained for major particulate matter control systems--multicyclones, fabric filters, wet (venturi) scrubbers, and electrostatic precipitators (ESP). In addition, this manual also discusses (through examples) the types of parameters that should be monitored for selected processes such as asphalt concrete plants, industrial boilers, and municipal incinerators. In many cases, process variables have a significant impact on the overall performance of the control equipment. Therefore, any recordkeeping system that overlooks process related data may be incomplete or ineffective in diagnosing equipment performance. Examples are provided that make use of combined process and control equipment data to illustrate the relationship between process and control equipment parameters. The difficulty in specifying process related parameters is that there are usually far too many parameters to be monitored and that specifying all of the potential monitoring areas may prove too burdensome and yet still not provide the degree of protection desired.

Although some recordkeeping activities are part of a statutory requirement, the emphasis of this manual is on recordkeeping as part of a preventive maintenance program. With an increased emphasis on maintaining long-term compliance with all regulatory emission limits, there is generally a need for a preventive maintenance program that uses an effective inspection and recordkeeping system. With greater interests on toxic air pollutants and continuous compliance, the role of recordkeeping is expected to be a significant part of the overall air quality management program in the future.

SECTION 2

PURPOSE OF RECORDKEEPING

The purpose of recordkeeping and any associated reporting requirements is often perceived differently by various individuals depending on their circumstances. For some, recordkeeping is merely a regulatory requirement that must be fulfilled. For others, recordkeeping is just a nuisance with no real purpose. On the other end of the scale there are those who want to maintain records on "everything" just in case they are ever needed in the future. Although the above observations represent extreme points of view, they are routinely encountered, sometimes within the same source.

The primary purpose of recordkeeping is not to merely fulfill regulatory obligations or to make what appears to be excessive demands on personnel and resources. Instead, a recordkeeping program should be part of a larger preventive maintenance program that enhances the long-term performance of the associated equipment (process and/or control equipment). Unfortunately, like most preventive maintenance programs, the recordkeeping program that must be established is very site-specific and considers a number of factors such as the adequacy of the design (redundancy), instrumentation, access for maintenance, and personnel requirements and availability. The same types of decisions that make the development of a preventive maintenance plan difficult are present in designing a recordkeeping program: how much data are needed, how often should the data be recorded and summarized, who will be responsible for gathering the data, who will analyze it, and how will it be analyzed. Personnel responsible for development of recordkeeping programs as part of the preventive maintenance program are usually trying to establish a balance between having enough versus having too much data. In this situation, the recordkeeping program serves as a tracking mechanism and helps provide the necessary data to evaluate the effectiveness of the overall preventive maintenance program.

2.1 REGULATORY REQUIREMENTS AND RECORDKEEPING

As mentioned previously, recordkeeping practices may be dictated by certain regulatory requirements. Some agencies (not related to the control of air pollution) have very specific information that is required on production levels and personnel. In the air pollution control field, very few specific data are required by regulations. In general, recordkeeping and reporting requirements typically emphasize the collection of continuous monitoring data, some production data, and excess emission reports. The Clean Air Act and State Implementation Plan (SIP) regulations codified into 40 CFR 51 give the State agencies the authority to require monitoring and recordkeeping as part of their program operation, but those powers have not been used extensively. Recent emphasis on upgrading the content of State construction and operating permits as well as those permits issued under prevention of significant deterioration (PSD) regulations have increased the overall recordkeeping and reporting requirements for certain sources. Many of these requirements have been imposed in an effort to maintain continuous compliance.

Although these permit requirements are generally more specific than found in the general regulations, they quite often do not require reporting of the data that are to be monitored (e.g., pressure drop) unless the parameter that is to be monitored exceeds some threshold value. At that time, the parameter would provide an indication that some operational change or maintenance is necessary. It should be noted that all values should be recorded and analyzed not just those that exceed the threshold value. An analysis of all the values enables one to establish a trend or pattern in the data, which can be very useful in diagnosing the problem rather that just indicating that a problem exists.

Care should be taken, however, to ensure that the data are not being collected because "its nice to have." The data required should be useful to both the agency and source in analyzing equipment operation and performance. Operating data that cannot be used for this or any associated purposes should not be required (although it may be monitored and even reported for other purposes not related to air pollution regulations).

In addition to operating data and performance related parameters, the regulations often allow recordkeeping practices to be specified as needed.

Again, some regulations require that specific maintenance activities be documented (e.g., continuous emission monitor zero and span checks, cleaning downtime, etc.). Most regulations, however, are not specific in this regard and agencies are accorded some discretion as to what maintenance records should be kept.

Regulatory recordkeeping requirements cannot ensure that compliance with the applicable emission limitations will occur. Equipment design and operation and maintenance practices will have the greatest effect on continuous compliance with the emission limitations. Recordkeeping is merely a tool that can aid in evaluating the overall performance of the source.

2.2 RECORDKEEPING AND MAINTENANCE PROGRAMS

Maintenance programs can be broadly divided into either preventive maintenance or breakdown (as needed) maintenance. Preventive maintenance is geared towards anticipating and preventing failure of operating components to provide "continuous" operation. Breakdown maintenance responds to equipment failure when it occurs and demands response when performance is adversely affected. Recordkeeping is normally thought of as being associated with preventive maintenance and less often with breakdown maintenance. Most effective maintenance programs, however, use elements of both preventive and breakdown maintenance to adequately respond to the day-to-day situations that occur in the plant environment. A key element in these programs is the method of recordkeeping and records analysis. By definition, preventive maintenance seeks to identify avoidable failures and prevent them from happening by routinely maintaining the equipment. The preventive maintenance program can either be directed by a schedule that does not rely on analysis of operating data (but may be dictated by operating history) or by interpreting operating data to determine if and when maintenance may be necessary prior to catastrophic failure of equipment or components. In this case, records help determine what action is needed and when.

In situations where preventive maintenance is impractical and the predominant form is breakdown maintenance, recordkeeping is not without its uses. For example, routine inspection and operating data may indicate that problems are occuring or that a failure may be imminent and that maintenance will be necessary. This may provide lead time to assemble the necessary

spare parts and schedule personnel so that when a failure occurs (or a shutdown occurs for some other reason), the maintenance will be quickly and efficiently performed. It is not unusual to see a mixture of preventive and breakdown maintenance at a facility because not all equipment warrants the same type of maintenance procedures.

The elements of preventive maintenance programs are often justified on the basis of reduced operating and production costs (cost/unit). This includes the cost of gathering data and reducing it as well as the cost for components and personnel to implement the various phases. In general, where the cost of preventive maintenance and breakdown maintenance are nearly identical, preventive maintenance may be difficult to justify although inspection and recordkeeping should be retained. Where costs are unexpected but preventable and malfunctions are severe, the use of preventive maintenance will be favored and, as mentioned previously, recordkeeping is an important part of the preventive maintenance program.

Unfortunately, for air pollution control, the cost of emitting pollutants short of a major equipment failure does not easily figure into the "cost" justification for a preventive maintenance program. This is particularly true with toxic pollutants where the cost of an accidential release may be substantial in terms of human health effects, but not easily quantifiable in terms of monetary value. Even in the absence of a formal preventive maintenance program, however, recordkeeping can and should be used to assist plant personnel in evaluating equipment performance and to establish good maintenance procedures.

The following two examples 1) show how good recordkeeping practices may be used to diagnose the existence of problems by presenting the changes that occurred over a period of time, 2) assist in the selection of maintenance to be performed, and 3) aid in the selection of the most cost-effective method of maintenance. These two examples, however, serve to illustrate a very important point: although better than adequate recordkeeping existed at both plants, compliance problems existed because plant personnel did not take the necessary time to examine the data available to them and to correlate the data with the observed results. The existence of a recordkeeping program does not guarantee continuous compliance with the emission limits, just as the lack of recordkeeping does not mean that noncompliance will occur. For a

recordkeeping program to be effective, however, it must be integrated into a program where essential data are gathered and interpreted to optimize the preventive maintenance efforts.

Example 1: An asphalt plant near a residential area has been the source of complaints for several months because of excess emissions from the stack. Stack opacity is very high and the scrubber is unable to comply with emission limits established for the source. There is no routine preventive maintenance program at the source and all work performed on the system has been breakdown maintenance. The plant does routinely, however, monitor certain parameters such as scrubber pressure drop and occasionally measures water flow from the pump. In addition, invoices for major purchases are available to provide some indication of the type of maintenance that has been performed.

Examination of the records available indicated that the problem had actually begun some 2 years prior when pressure drop across the scrubber began to drop despite closing the scrubber throat and increasing the scrubber water flow from 250 gal/min to 450 gal/min. The scrubber had been able to achieve a 26 in. H_2O pressure drop but 2 years later could only achieve 17 inches. In addition, repair records indicated that the fan shaft had been replaced three times because of damage from fan in-balance ($4000 each). The fan also showed considerable erosion and would require the replacement of wear plates built on the fan blades.

Access to the scrubber throat was provided by an access hatch above the variable throat held to the scrubber by 12 bolts. The access hatch had not been opened in the 5 years that the scrubber had been operating. With the plant shutdown and cool, the hatch was opened and the variable throat examined. It was found that the plate used to control throat area and, hence, pressure drop had eroded severely. Examination of the scrubber arrangement indicated that gas flow and particulate matter loading was biased heavily towards one side of the scrubber because of a design deficiency in the duct work. The problem could be corrected by redesigning and reconstructing the duct work (at a cost of several thousand dollars) at the scrubber inlet. A more suitable solution was to replace the scrubber's variable throat, which cost approximately $75, and to routinely visually check the plate at least once per year for wear and replace the plate as necessary. This restored scrubber performance had also reduced the problems the plant was experiencing with the fan. In this case, the data were adequate to suggest the source of the problem and ultimately led to a reasonable, low-cost solution, if only time was taken to review the available information.

Example 2: In this example, cost became a compelling factor but some costs were ignored because they could not be easily quantified. A manufacturing facility operated three coal-fired boilers to produce steam. Typically, only two of the three boilers operated (each was rated for 100,000 lb steam/h or approximately 120×10^6 Btu/h heat

input) to produce an average 85,000 lb steam/h each. All three stoker-fired boilers were ducted to a large four-compartment pulse-jet fabric filter containing 210 bags/compartment. The bags were felted fiberglass that cost $65/bag.

This facility had a long history of bag problems. Typically, bags were changed approximately every 90 days because the boiler opacity was above the 40 percent limit allowed by the State agency. In fact, it was not unusual for the boilers to be routinely violating the emission standard during the previous 30 to 45 days before the bags were changed. After the bags were changed, pressure drop across the fabric filter would gradually increase from about 4.5 inches to 14.5 inches over a 30-day period and then dropped to approximately 10 to 12 inches as the bags failed. Unfortunately at this pressure drop, the fan had reached the fan limit and the boilers were unable to produce additional steam if there was a demand above these operating levels (more common in winter). Thus, production and/or heating would suffer because of the inability to produce more steam when needed.

Continuous recorders were available for all parameters needed such as steam flow, pressure, temperature, boiler oxygen after the economizer and after the air heater, boiler CO levels, flue gas temperature, pressure drop, and opacity. These same parameters and others were also recorded hourly by the boiler operator on the boiler log sheets. Plant personnel were aware that combustion problems probably contributed to fabric filter failure. Boiler oxygen was exceptionally high at 14.0 percent O_2 at a temperature of 385°F. The energy loss from this operation was substantial as lower O_2 and temperatures were possible. However, the major evidence concerning combustion was the high CO levels in the flue gas and the quantity of unburned carbon in the fly ash. The heat content of the flyash was 7,800 Btu/lb (the coal heat content was only 13,000 Btu/lb) and indicated that substantial quantities of unburned coal were entering the fabric filter.

The symptoms exhibited indicated that poor combustion was a major contributing factor to the failures experienced with the fabric filter. In addition, reduced efficiency because of carbon loss meant more coal had to be burned, which generated more particulate matter and SO_2 than origially estimated. Although poor air distribution could contribute to poor combustion, the problem was discovered after examining the coal supply. Coal properties were such that very fine coal was being fed to the spreaders. Unfortunately, spreader stokers are very sensitive to fuel size. As a result, there was poor combustion and the carbon carryover, as a result of the poor combustion, blinded the bags.

In this situation, the most obvious and effective solution was to change coal size characteristics from the very fine size noted in the pile to the ¼ x 1½ distribution needed for proper operation. Based on operating data, the stack loss included a 12.4 percent stack loss (14.0 percent O_2 at 385°F) and a combined combustible loss of 11.91 percent (2.78 for CO, 9.13 for carbon in the fly ash). By changing coal size, the boiler efficiency was expected to improve substantially by burning CO and

carbon in the boiler rather than losing them to the atmosphere. There would also be an opportunity to reduce both oxygen content and flue gas temperature to further improve efficiency and to reduce the uncontrolled emission rate of particulate matter and SO_2 from the boiler. An estimate of the improvement would raise the boiler efficiency from 73.5 percent to 84.6 percent at the improved combustion levels.

However, the change in coal quality caused the cost per ton of coal to increase. The poor quality coal was delivered at a cost of $30/ton and the double-screened coal cost $37/ton and could quite possibly increase to $40/ton if the plant burned this coal instead of the coal being supplied. The plant realized that this would increase the operating costs for the boiler even with the improvement in boiler efficiency. A complete analysis, however, had not been performed to quantify the cost of changing coal. A more complete analysis indicated that at $37/ton, the boiler would cost more to operate but when the cost of fabric filter bag changes were included ($60,000), the more expensive coal yielded a savings of $16,900 over each 3-month period. At $40/ton, however, the cost resulted in a net increase of $36,375 per 3-month period giving the appearance that it was more desirable to burn the cheaper coal and replace the bags quarterly as the plant had done previously. Although other factors were overlooked such as increased wear on other components (fans, conveyors), increased cost of moving waste materials, and loss in production due to steam limitations, the most obvious item missing was the economic beneift derived by operating 30 to 45 days out-of-compliance with emission limitations. If the plant had been forced to replace the bags once every 30 to 45 days when bag failures began to significantly affect emissions, the economics would have, without question, been more compelling for the source to change coal.

2.3 ELEMENTS OF A RECORDKEEPING PROGRAM

A recordkeeping system should not be established in a haphazard manner. To the extent possible, a recordkeeping program should be designed to provide the necessary level of useful information with a minimum amount of personnel resources to complete the necessary checks and paperwork. In a preventive maintenance program, it is often the paperwork that receives the least attention because it is the most cumbersome daily activity to complete.

A recordkeeping program should contain five basic items which, in some cases, may add to the existing paperwork load. These items are an equipment record, a checklist, an inspection schedule, inspection report, and equipment/maintenance cost record. Some of these items can be combined to fulfill several needs. For example, operating logs can be used for scheduling, and reporting if certain key parameters are selected for routine monitoring. The need to obtain complete and accurate information must be balanced by the

necessity to keep the recordkeeping system simple to maintain. This will require careful evaluation by responsible personnel regarding what data are necessary and important and what is secondary or "nice to know" data. If there is already a functioning recordkeeping system used by the plant, it may be possible to modify it to supply the necessary information. If not, then the opportunity to design a workable system exists.

2.3.1 Equipment Record

An equipment record, although considered essential to the establishment of a preventive maintenance program, may be of limited use on a day-to-day basis as the equipment record usually takes the form of specifications and design parameters rather than recording a set of hourly values. A system should be devised to catalog this information because even a small industrial plant can have hundreds of subcomponents where the design information is critical. Very often, this critical information becomes misplaced and when the information is needed to determine the initial design conditions parameters, the data are unavailable.

Generally, the best method of keeping these data are to have a central filing and retrieval system. In smaller operations, this may be an office with a bookshelf or two devoted to the storage of the operations manuals accompanied by drawings and blueprints kept in a separate but nearby file. As plants get larger, however, the number of manuals and specifications that need to be maintained becomes very large and a more sophisticated storage and retrieval system is needed. In these situations, a "catalog" system works well where documents are given a file number for later retrieval. The catalog can consist of cards kept in a filing system according to process or control equipment grouping. The catalog may be further subdivided into major subassembly groups. To locate the necessary data, one must locate the major grouping and subgroup, obtain the file number, and then go to that file location to obtain the necessary data.

A variation in this procedure is to list all major components and subassemblies under a category either on paper or by computer. Again, all that is necessary is to look up the major heading and then the subcategory to find the appropriate file number. In fact, either system allows the addition of basic design information in the catalog that might save time and effort in

finding the appropriate file. Figure 1 is an example of a catalog system that is used by a large pulp and paper mill.

The equipment record should be kept up-to-date. If modifications to a system are made (e.g., changing the number and size of tubes in a multicyclone) this information should be reflected in the equipment record. Old or out-of-date information should be removed from the system.

2.3.2 Inspections and Monitoring

As part of a preventive maintenance program, one of the first decisions that must be made is what items will be inspected and/or monitored? Items that will be inspected need some type of form or method of reporting what was found whether it is numerical value or merely an acknowledgment of proper operation. The basis for deciding what will be routinely inspected and monitored is usually determined by its relative importance to the plant operation. For example, items (and parameters) that are essential to the operation of the process or the plant and whose failure would cause substantial damage or loss of production capability would naturally receive more attention than those items that are easily replaced or of have minor consequences in terms of the overall plant operation. Other items that may receive more frequent inspection or continuous monitoring are expensive components or items that can lead to more serious failures if problems are not corrected in a reasonable time period.

The emphasis on cost may appear to ignore regulatory requirements that are necessary in order to comply with the emission limitations. There is, however, a cost associated with continuous compliance when a malfunction occurs. This cost may be in the form of lost production or noncompliance penalties or both. The routine inspection and monitoring of control equipment operating characteristics and key process parameters helps ensure continuous compliance with the emission limits by providing information to plant personnel to evaluate the situation and to respond as needed.

2.3.3 Inspection Reports

The inspection and monitoring program generates the need to report or record data, to verify that proper items have been checked, and that any needed maintenance is scheduled. The report may be only a checklist to indicate that certain items were inspected or it could include important

15 - LIME & SALT CAKE STORAGE, and #5 KILN & CAUSTICIZING SYSTEM

supersedes 8-1-84 February 1, 1985

	1567-63	BURNER, #5 kiln, flame safeguard system
9-1-D4	1567-64	#2 PUMP, oil for #5 kiln, Roper size 1H15, S/N F3033, 20 hp, 1200 rpm
9-1-E1	1567-70	FAN, primary air, #5 kiln, Lamson Blower model 515, 5-stage, 550 scfm @ 5 psig, Stoddard silencer model F64-5, 30 hp, frame 286T, 3600 rpm, rated 36.8A @ 460V
	1567-71	FAN, strong NCG to #5 kiln burner
	1567-80	FAN, induced draft, #5 kiln, Champion, 76,000 cfm @ 9" S.P.
7-48	1567-81	DRIVE, I.D. fan, #5 kiln, 200 hp, frame 5008, 900 rpm, rated 246A @ 460V, Emerson variable frequency drive model A.S.4470
	1567-82	DRAFT CONTROL, I.D. fan, #5 kiln
7-1-84	1567-90	CONVEYOR, belt, #6 & #7 filters to cross screw conveyor, 20" belt, 350 fpm, 5 hp, 1800 rpm, Falk 52-50FZ2M, 20.52 ratio
7-1-B5	1567-91	CONVEYOR, screw, lime mud cross to feeder, 22" dia x 9'-5" long, 29.0 rpm, 50 hp, frame 326T, 1800 rpm, rated 59.5A @ 460V, Falk 1080FZ2A, 25.63 ratio
7-1-C1	1567-92	CONVEYOR, screw, lime mud feeder to #5 kiln, 22" dia x 11'-2" long, 29.0 rpm, 50 hp, frame 326T, 1800 rpm, rated 59.5A @ 460V, Falk 1080FZ2A, 25.63 ratio
7-1-B5	1567-93	VIBRATOR, lime mud, #5 kiln
	1568-00	
	1569-00	
	1570-00	
	1571-00	
	1572-00	ENCLOSURE, #5 kiln precipitator, F.L.Smidth, 2 units (north/south), 3/16" steel walls, each unit consists of two sections 22' high x 16-1/2' wide x 20' long, design flow 76,000 cfm @ 9" H20, efficiency 99.88%
	1572-01	PLATES, #5 kiln precipitator, 19' 8-1/4" nominal height, 1'-9" wide, 16 ga mild steel, 35,120 sq ft collecting surface area
	1572-02	STACK & BREECHING, #5 kiln, 4'-6" O.d., 3/16" 316L S.S. stacks, one each precipitator, 3/16" mild steel breeching
7-1-C2	1572-03	DAMPER, precipitator inlet, south side, F.L.Smidth disc valve C, 2 hp, 1200 rpm, rated 3.7A @ 440V
7-1-C3	1572-05	DAMPER, precipitator inlet, north side, F.L.Smidth disc valve C, 2 hp, 1200 rpm, rated 3.7A @ 440V
	1572-10	HIGH VOLTAGE LINES, SWITCHES & INSULATORS, #5 kiln precipitator
7-1-E1	1572-11	#1 TRANSFORMER/RECTIFIER, #5 kiln precipitator, south side outlet, 33.6 KVA, 440 VAC input, 88,000 VDC output, NWL transformer model 28319
7-1-E1	1572-12	#2 TRANSFORMER/RECTIFIER, #5 kiln precipitator, south inlet, 33.6 KVA, 440 VAC input, 88,000 VDC output, NWL transformer model 28319
7-1-F1	1572-13	#3 TRANSFORMER/RECTIFIER, #5 kiln precipitator, north outlet, 33.6 KVA, 440 VAC input, 88,000 VDC output, NWL transformer model 28319
7-1-F1	1572-14	#4 TRANSFORMER/RECTIFIER, #5 kiln precipitator, north inlet, 33.6 KVA, 440 VAC input, 88,000 VDC output, NWL transformer model 28319

Figure 1. Example of catalog system used by a large pulp and paper mill.

numerical information along with a narrative so that the findings are made clear. It is usually at this point that many recordkeeping systems begin to experience difficulty because the paperwork becomes the most demanding part of the preventive maintenance program. The problem is not so much of one of being unwilling or unable to perform the routine monitoring and inspection of key parameters or equipment as it is in analyzing what the information means, what actions are required, and reporting the findings to the appropriate individuals within the organization. Strip charts can record key parameters and people can follow a checklist and fill in forms where data are requested but these are of little use if they are not in a format that may be easily analyzed or if they are not examined at all. That is why plant personnel should carefully examine what parameters and checks are most useful and carefully select those items to be monitored.

Inspections and reports may also be performed in conjunction with scheduled or requested maintenance as a follow-up to verify correction of a noted problem. The decision to include this information with the "normal" inspection reports or to include it only in the equipment/maintenance record will depend in part on how retrievable both elements of the system are and the degree of detail provided. It is sometimes better to duplicate this effort than to have the possibility of pertinent information being lost. For example, if a problem is noted and maintenance is requested, it does personnel tracking the preventive maintenance program little good if there is no way to report back the findings and actions taken. As a result, key information that is needed to fine tune both the recordkeeping and preventive maintenance program may be lost.

As with the inspection scheduling, the inspection reports and records should be reviewed periodically (quarterly to semi-annually) to determine if the information gathered is adequate. If there are areas in which data are being gathered that are of little use, these should be eliminated. Any time the level of paperwork can be reduced without affecting the overall quality of the program it will, most likely, be appreciated by the people who have to take the time and effort to provide the information. Reducing the "clutter" of unneeded and unused recorded data may also allow or encourage personnel to focus on those recordkeeping items that are of greater importance.

2.3.4 Equipment Maintenance/Cost Records

The most workable system for a wide variety of facility sizes and types appears to be a system based on job or work orders. For the smallest facilities, a simple maintenance log with pertinent information (such as description of work performed, cost, and time required) may be adequate. The work order system, however, has several advantages over a simple log book. First, the work order provides written notification that maintenance has been requested. Second, it can aid in the scheduling of maintenance personnel particularly when the work is prioritized. Third, the work order should provide a written record of what was found, what was done, and if any action was taken to correct to problem, or whether further action is required (and scheduled). For example, in an ESP, if a broken wire was suspected of causing the deenergization of a power supply, a work order might specify that the cause of the ground should be found and removed. Then during a short boiler outage, maintenance personnel would be scheduled to repair the unit. If they found the cause was a random wire break, they would remove the wire, possibly replace it, note its location, and document on the work order. If some other cause was found (e.g., a warped plate that required removal of extra wires to prevent breakage and scheduling of straightening for a longer outage), these would be recorded as well as any additional maintenance performed or scheduled for a later date. Lastly, work orders can be sorted several ways for accounting purposes. They can be sorted by labor craft, equipment type, process, and by type of problem. Whether done by hand or by computer, the work orders can summarize the results of a preventive maintenance plan by showing if failures are occurring "randomly" or if the maintenance and corrective maintenance are not addressing the proper causes of problems. The cost of such problems would also be available to estimate the cost of changing the preventive maintenance program. Appendix A contains an example of a work order form.

> Example 3: A pulse-jet fabric filter on a small source works well, when it is working. But every 45 to 60 days the bags have to be changed because they become blinded and the pressure drop has gradually increased from 4 inches when the bags are new to 15 inches just before the bags are changed. The process dust caused by the restricted ventilation rate causes a nuisance and many citizen complaints are received because of the fugitive dust escaping from the plant. A complete bag change

costs between $2,500 and $2,800. The plant routinely checks pressure drop and cleaning system operation but is unable to stop the deterioration. A change in strategy and new options need to be considered. These options include a modification to the process, a change of control equipment, or a change in maintenance. Lets examine the problems more carefully.

Plant personnel were aware that some changes were needed and at current performance levels that excessive costs were being incurred. No process changes seemed possible to alleviate the problem as the dust should not have been causing the observed blinding problems. A change to a new process might lower the uncontrolled emission rate without substantially changing the particulate matter characteristics. A change from a fabric filter to a scrubber was possible but considered undesirable because of the water discharge regulations. The most obvious solution appeared to be a continuation of the process of changing all the bags but at shorter intervals to prevent the fugitive emissions and citizen complaints. Unfortunately, the plant did not use the information available to discover the source of the problem and was only responding to a symptom because the cause of the bag blinding problem was water and oil carryover from a pulse-jet air supply compressor that needed to be rebuilt or replaced. For the cost of three complete bag changes, the compressor could be replaced with a new one with an air dryer and the bag blinding problems "solved." Plant personnel had the cost and performance data available and were ready to make changes. But the key was to use the data collected to find the cause of the problem rather than treating the symptom. The plant's own data indicated they were treating the symptoms.

Larger facilities that use or are familiar with a work order system will find that the inclusion of air pollution control equipment into the system will present very few difficulties. A few additional records and analysis may be needed but the function of the system will be the same as for process equipment. There will be the same need for a priority system and a method to ensure that the findings are sent to appropriate departments and personnel. For those just beginning a system, careful planning and adequate time and training will be needed to ensure that the system is effectively implemented.

2.3.5 Summary

Recordkeeping can be a monumental task whether it is part of a preventive maintenance program or not. The ability to retrieve and analyze the data can present a significant logistics problem and requires careful planning to make the recordkeeping program effective. The differentiation between required data and "nice to know" data is critical in attempting to keep the paperwork at a minimum. The following sections for the various types of

control equipment provide examples of the type of information that should be considered and, indeed, may be required in a permit or to operate an effective preventive maintenance program. The list is not all inclusive and special conditions and exceptions can always be found but, hopefully, most situations are addressed.

SECTION 3

MULTICYCLONES

Of all the particulate matter control equipment groupings discussed in this manual, multicyclones probably represent the least complicated control devices. Generally equipped with few moving components, these devices have the potential for reliable service if it were not for two limitations. First, multicyclones have a tendency to plug. Although some units see years of operating service without problems, others need to be taken out of service almost weekly for cleaning. Second, of all the control equipment types, the multicyclone generally does not perform well when the gas volume through the device decreases. The performance of a multicyclone is closely tied to the volume of gas passing through it. Although there are designs that try to reduce or overcome these limitations, most do not address these problems.

The simplicity in design means that there are relatively few parameters to be monitored for multicyclones. Unfortunately, the parameters that can be monitored do not provide the best indication of control equipment performance. There is no direct measure of the amount of inertial forces applied within the collector although this might be inferred from the gas volume. The parameters available to be monitored include:

Operating

Pressure drop

Temperature

Fan motor current

Dust discharge operation checklist

Opacity

Maintenance

Gasket replacements

Tube replacement

Vane replacement

Smoke-bomb tests

Tube pluggage

It should be noted that although opacity is included on the multicyclone opearting parameter list, it is not an effective parameter to be monitored as it is for other types of control devices discussed later. In general, opacity is of little use for multicyclones because they are usually not capable of capturing small size particulate matter in the light scattering range. Thus, substantial changes in particulate matter emissions may occur without any apparent change in opacity. Conversely, a change in opacity may mean that a process change has occurred, which changes the particle size distribution entering the collector. Notwithstanding this limitation, opacity may be worthwhile to record in that it will indicate a change in fuel or process conditions that tend to generate excessive quantities of fine particulate matter, which readily pass through the multicyclone leading to opacity violations and possible mass emission standard violations.

3.1 OPERATING RECORDS

Parameter Measured: Pressure drop

Applicability: All sources

Methods of Measurement: Manometer, magnehelic, and continuous strip chart recorders

Limitations: Pluggage of pressure taps, will not necessarily indicate tube pluggage problems

The most common monitoring parameter for multicyclones is pressure drop. Pressure drop provides an indication of gas flow through the multicyclone because what is being measured is the resistance to flow through the turning vanes and tubes, which provides an indication of the amount of force being applied to remove particles from the gas stream. Within limits, a higher pressure drop means more removal force and higher collection efficiency. Pressure drop will vary with gas flow as increases or decreases in gas volume through the collector will correspond to increases or decreases in pressure drop.

Pressure drop may also be a useful indicator of pluggage of the turning vanes. In theory there should be an equal gas flow through each tube and

blockage of the tube inlet turning vanes will force gas to travel through other tubes and increase the gas volume (and velocity) through each tube. This will, inturn, increase the pressure drop. It takes, however, a number of tubes to become blocked before there is a noticeable increase in pressure drop, which would have to be coordinated with some other parameter such as gas volume and temperature to determine if pluggage is occurring. Normal variations in gas volume will produce larger shifts in pressure drop than isolated tube pluggage.

Pluggage of the bottom of a multicyclone tube, which is common, or the outlet tube, which occurs less frequently, will rarely be noticed as a result of a change in pressure drop because 80 to 85 percent of the pressure drop is generated across the turning vanes. Therefore, it is possible to have most of the multicyclone discharge tubes plugged and not notice a discernible change in pressure drop.

Some operations monitor pressure drop on a continuous basis (e.g., some industrial boilers and other boiler applications of multicyclones). Most, however, only periodically monitor the values. Minimum time periods should be once per day. If existing process parameter monitoring allows for more frequent monitoring and recording than once a day, more frequent monitoring should be conducted.

Parameter: Temperature
Methods of Measurement: Thermocouple
Applicability: All high temperature sources
Limitations: None

Temperature problems are usually not associated with multicyclones. Two areas of concern, however, are excessive temperature that affects some gaskets used to seal the tubes and tubesheets and the possibilities of low temperatures causing sticky particles that lead to or aggrevate pluggage problems. High temperatures may come from process operation or from hopper fires (combustion sources). Hopper fires may also result in other problems such as tubesheet warpage and annealing of the steel in the tubes and turning vanes resulting in exceptionally fast abrasive wear.

Temperature monitoring should generally be continuous at the multicyclone outlet. The outlet should be equipped with temperature alarms to

alert operator of excessively high or low temperatures in the collector. In addition, any periods of high or low temperatures should be noted in a log book or on the operating records. Temperature will also affect pressure drop and fan motor current.

Parameter: Fan motor current

Method of Measurement: Ammeter (inductance-type)

Applicability: Moderate to large sources with substantial variations in gas flow

Limitations: Electric drives only. Steam driven fans not measureable.

Fan motor current provides an indirect measurement of the gas flow rate through the system. Higher gas volumes usually mean high amperage drawn by the fan motor. Even with different damper arrangements, this is qualitatively true. This is useful in determining if an observed change in pressure drop is caused by a change in gas flow or from pluggage within the multicyclone. It should be noted that gas temperature affects the gas density, which will affect both pressure drop and fan motor amperage. An increase in gas temperature will decrease gas density and increase actual gas volume, which may reduce pressure drop and the amperage drawn by motor. Thus, readings should be normalized to a constant temperature [i.e., Amp (70°F) = measured amps $\times \frac{T + 460}{530}$ where T = temperature, °F)].

Fan motor current may be measured and recorded constantly by a strip chart recorder. The minimum recordkeeping requirement, however, should be once per day whenever pressure drop is monitored (or at every pressure drop reading).

Parameter: Dust discharge operation checklist

Method of Measurement: Visual

Applicability: All sources

Limitation: Quantitative measurement is often not practiced

The proof of operation of any multicyclone is that material is being collected and discharged from the device. Although a precise measurement of the amount of material captured is not required, periodic checks of the dust discharge should be conducted. This should include checking of the rotary airlock, double gate valves, or other sealing devices for proper operation and maintenance of all associated conveying systems. Minimum frequency is

usually once per shift, although multicyclones with very heavy dust loadings should probably be checked more frequently to avoid serious hopper pluggage problems. If hopper vibrators are used to help remove dust from the hoppers, they should also be checked during routine inspections.

3.2 MAINTENANCE RECORDS

Work order records should provide adequate information on maintenance work performed on multicyclones. The following items should be included if maintenance in these areas is performed. Of course, records from each internal check should always be maintained.

Maintenance Parameter: Gasket replacement
Applicability: All sources
Limitations: None

Gaskets fail because of age, excessive heat, or improper installation. The gaskets between the dirty side and the tubes are particularly susceptible to failure if not properly installed or maintained. The location of all failed and replaced gaskets should be maintained. Erosion of the tubesheet where a gasket has failed is possible because of the pressure differential between the two sides of the tubesheet. This may make adequate installation of replacement gaskets difficult or impossible and may eventually require replacement of the tubesheet or the complete "blanking off" of a tube from the gas flow.

Maintenance Record: Tube replacement
Applicability: All sources
Limitations: None

Some sources are capable of operating for 20 years or more without having to change tubes while others may only be capable of operating from 3 to 6 months before the tubes are severely worn. The wear characteristics are very site-specific. Isolated worn tubes, however, may indicate a flow or particulate imbalance problem in the collector, that may require modification to extend collector life and to improve long-term performance. The location and extent of tube wear as well as any tube replacement should be noted.

Maintenance Record: Vane replacement
Applicability: All sources
Limitations: Multicyclones with replaceable vanes

The same considerations that apply to tube replacement apply here as well. A few multicyclone designs are equipped with replaceable vanes instead of vanes that are cast into place.

Maintenance Record: Smoke-bomb tests
Applicability: All sources
Limitations: Cost

A smoke bomb test of a multicyclone is both expensive and time consuming. It may also be the only way to document the presence or lack of tubesheet/hopper leaks or dirty-side/clean-side leaks. The location of any leaks noted during such tests should be recorded. In addition, such tests will also document the presence of tube pluggage. Again, pluggage problems should be recorded and efforts made to eliminate the pluggage as soon as possible.

A smoke bomb test basically involves the closing (stoppering) of all outlet tubes and dust discharge tubes. Smoke bombs are lit while the multicyclone is pressurized to draw the smoke through any openings. Smoke is very visible and a well sealed collector will show no leaks.

Maintenance Record: Tube pluggage
Applicability: All sources
Limitations: None

Periodic checks (when the collector is off-line) should be performed for indications of tube wear and pluggage. Any pluggage should be noted in the records giving the tube location and the pluggage location (turning vane, dust discharge, outlet). Most often tubes near the wall see the greatest pluggage. The frequency of such checks will depend on a number of factors. Those exhibiting few problems may only need periodic checking once or twice per year while others may need to be checked once per week. A good starting point is monthly checks that are adjusted on an as needed basis.

SECTION 4

FABRIC FILTERS

Of all the particulate matter air pollution control devices, the fabric filter probably receives the widest application in terms of the range of source types and sizes. Fabric filters range in size from two to four bag units to greater than 2,000 bag units and with proper fabric selection they can be operated at temperatures ranging from ambient to 550^{o}F. The amount of available cleaning energy supplied as well as inlet particulate matter loading will help determine the physical size requirements of the fabric filter.

All fabric filters rely on the same method of operation to remove particulate matter from the gas stream. The fabric provides the support material for the establishment of a dust layer or dust cake that performs most of the filtration. During operation, this dust layer increases in thickness and, thus, increases pressure drop across the fabric filter. Periodically the dust cake must be removed by the cleaning system, which may be categorized as either pulse cleaning, reverse air, or shaker. The low energy systems (shaker and reverse-air) require lower air-to-cloth ratios (acfm/ft^2 fabric) typically in the range of 1 to 2 acfm/ft^2. The pulse cleaning systems provide a greater amount of cleaning energy and they usually have higher air-to-cloth ratios (4 to 12 acfm/ft^2). All fabric filters are sensitive to the process operation and dust characteristics. As such, the records obtained must be coordinated with appropriate process data.

The list of operating and maintenance related data and records that may be used is limited. Some of the monitored information would be useful only on larger or higher temperature sources but there are enough of these installations to warrant their discussion. Although the data are limited, the information provided is very useful in evaluating performance and maintenance considerations. These data include:

Operating

Pressure drop

Temperature

Opacity

Fan motor current

Inspection Checklist

Cleaning system operation

Dust removal system operation

Maintenance Records

Bag replacement location

Cleaning system components

Dust discharge system components

Other miscellaneous components

There may also be other data that may be of use such as process data, bag-failure analysis, etc., that may influence the long-term performance of the unit, however, the data to be gathered must be determined on a case-by-case basis.

4.1 OPERATING RECORDS

This subsection summarizes the key operatiing data that should be obtained when a fabric filter is in operation. There may be several methods of obtaining these data and site-specific factors will govern the method selected.

Parameter: Pressure drop

Applicability: All installations

Method of Measurement: Manometers, magnehelic/photohelic gauges, pressure/electronic converters for continuous readings

Limitations: Pluggage of pressure taps, leakage in pressure lines

Pressure drop is one of the more useful parameters that can be monitored on a fabric filter. When taps are provided for the inlet and outlet static pressure, the pressure drop across the bags provides an indication of the resistance to gas flow and a relative indication of bag cleaness. Under normal circumstances, pressure drop will range from 2 to 8 inches with 3 to 6

inches H_2O being most common. Most often, a substantial change in pressure drop will indicate the existence of a problem. If the pressure drop decreases, it may indicate loose bags, holes in the bags, or problems with a tubesheet. If the pressure drop increases, it may indicate a cleaning system failure, blinding of the bags because of changes in the dust properties, and even a dust removal system failure. Failures such as these are usually noted in periods ranging from a few minutes to several days. Much more gradual changes may be noted over weeks or months if bags are blinded due to excessively high A/C ratios, fine or sticky particulate matter, or acid and moisture dewpoint problems. The higher pressure drops observed may be used to schedule bag replacement because the bag is reaching the end of its useful life.

> Example: A fabric filter with pulse cleaning was used to remove sander and planes dust from the gas stream at a furniture plant. The A/C ratio varied between 8.5 and 11.0 depending on the number of machines operating and the bag conditions. When the bags were new (filtering dust layer established) the pressure drop was typically 3.5 to 4.0 inches. Over a 6-month period, the pressure drop gradually increased to approximately 8.5 in. H_2O. Above 10 in. H_2O, flow was restricted to the point where the hood systems would not efficiently pick up the dust (causing fugitive emissions) and bag failures would increase from virtually none to one to two per day. Thus, the plant scheduled bag changes every 6 months to minimize the energy required to overcome the pressure drop and to reduce periods of noncompliance. Failure of the cleaning system caused an increase in the pressure drop to be noted within several hours. Holes in the bags caused both decreased pressure drop and high opacity.

One of the problems associated with measuring pressure drop is pluggage of the pressure taps, particularly the inlet tap. The taps should be cleaned or periodically back-flushed with air so that valid data can be obtained. Although there is no flow of gas and particulate matter in the static pressure lines, there may be some deposition of moisture and particulate matter in the instruments, which may require periodic changing of the manometer fluid or cleaning the instruments.

Larger, multicompartmented fabric filters equipped with shaker, reverse air, or plenum pulse cleaning may be equipped with continuous strip chart recorders for overall recording of pressure drop. These charts are useful for diagnostic confirmation that each compartment is isolated for cleaning.

As each compartment is isolated, the pressure drop should increase and as it is returned to service the pressure drop should decrease.

The use of individual manometers or gauges on each compartment is less useful than an overall pressure drop reading. Each gauge will read nearly the same pressure drop as the overall value because static pressure will tend to balance over the system although flows may vary in each compartment. The individual pressure readings are useful, however, for determining if the compartment is properly isolated during cleaning (or for on-line maintenance) because a no-flow condition should yield a "0" pressure drop reading.

Parameter: Temperature

Applicability: High temperature conditions (non-ambient)

Method of Measurement: Thermometer, thermocouple or thermistor for continuous readout, temperature alarm and control

Limitations: Improper location due to stratification, slow response to temperature changes, wrong thermocouple type for electronic conversion

There are a wide variety of bag fabrics with a number of characteristics that are important to the operation of the fabric filter. One of the most important characteristics is the temperature limitation of the fabric. The potential to operate the fabric filter above the maximum allowable fabric temperature can cause concern about fabric life. The loss of fabric integrity may result in pinholes, tears, or destruction of part or all of the fabric in the bag(s).

Temperature indicator/recorders are used most often on "hot" sourses (e.g., combustion sources or metal processing facilities). A temperature monitoring device, however, may be recommended on any process that has the potential to operate at 50°F above ambient temperature and within 50°F of the permissible temperature limit of the fabric. The temperature monitoring equipment should be located to measure gas temperature on the inlet of the fabric filter. Temperature losses as great as 100°F have been noted between the inlet and outlet readings in some situations because of inleakage and heat loss from the fabric filter enclosure. Measurement downstream of the collector may result in a false sense of security because bags may be subjected to excessive temperature although there may be no indication of problems.

The use of electronic temperature measuring devices with output displays in the control room are most useful too as they provide the operator with continuous temperature data. In addition, the temperature output may be connected to an alarm circuit to provide warning of high temperatures and potential damage to the bag. The alarm setpoint should be set high enough not to be a nuisance but low enough to provide the operator with time to react to the situation to prevent fabric damage. Generally, the temperature setpoint will be 25 to 75 degrees below the maximum allowable fabric temperature. More sophisticated temperature monitoring systems can evaluate not only the temperature but the rate of temperature change to govern alarm conditions.

In addition to high temperature conditions, temperature monitoring equipment may also be useful in situations where acid or moisture dewpoints are of concern. In some applications, operation of the fabric filter below dewpoint conditions may result in bag blinding and/or acid attack of the fabric resulting in unacceptable performance.

Temperature monitoring is of little use on fabric filters that operate at or near ambient temperature and collect a flammable dust. The monitor is usually unable to detect a fire condition unless measurement is within or downstream of the collector. Even then, as fire protection the thermocouple would react too slowly to be of use.

Not all sources that can be defined as a "hot" source will elect to continuously record inlet temperature. This may be suitable for sources that experience little variation in operating temperature such as product dryers that operate on a constant feed. The temperature readout, however, should be prominently displayed for the operator and the temperature data should be recorded each time other operating data are recorded.

Parameter: Opacity

Applicability: All fabric filter applications except some positive pressure units

Method of Measurement: Reference Method 9, opacity monitor

Limitations: Reference Method 9 reading requirements may miss "puffs"; opacity monitor impractical for small sources. Must have particles less than 2 microns to scatter light. Condensation may cause false indications of problems.

In a large number of applications, opacity observations or measurements are useful indicators of fabric filter performance. As long as there are particles up to the 5 to 8 micron range to scatter light, the gas stream will be capable of exhibiting opacity if there are problems within the fabric filter. The opacity measurement can be used to determine the presence of bag leaks and, if analyzed carefully, the measurements can also identify the rows or compartments where the leaks may be occurring.

In most fabric filter applications, the opacity that is visually observed or measured with a transmissometer should be extremely low. The measurements with a transmissometer, however, will be much more sensitive to slight variations, particularly at low opacity levels. Observation of opacities above 10 percent generally indicate that some problems exist within the fabric filter and that maintenance is required. Continuous elevated opacity indicates that the leak could be caused by a bag tear, tubesheet leak, or fallen bag whereas puffs associated with the operation of the cleaning system may indicate the presence of pinhole leaks that reseal with the dust layer between cleaning.

Opacity should be visually observed at least once per day. For plant personnel involved in maintenance or preventive maintenance programs, it may not be necessary to make observations in strict accordance with Reference Method 9. What is important is observing the base opacity and any puffs associated with the cleaning system operation. For sources equipped with opacity monitors, the monitor should be allowed to record data on a "real-time" basis and not a 6-minute average for at least one complete cleaning cycle once per day. The presence of spikes should be correlated with compartments or rows of bags if they are present on the strip chart recorder.

For sources that do not have enough small particles to provide a reliable opacity indication, other methods for evaluating performance are necessary. This may include daily checks of the fabric filter outlet or clean-side for excessive deposits. These checks should be made daily so that loss of performance and damage to other bags can be minimized.

Parameter: Fan motor current (amps)

Applicability: All fabric filter systems with electric drives

Method of Measurement: Ammeter

Limitations: Precise relationship between motor current and gas flow requires fan curve. Electric drives only.

The use of fan motor current to provide an indication of the gas volume being moved through the exhaust system is becoming more common in facilities where energy use and monitoring is of concern. Because there is a relationship between fan motor current (and horsepower computed from the fan motor conditions) where more current means more energy and (usually) more gas volume through the system, it is a simple procedure to obtain a relative indication of gas flow.

The measurement of fan motor current is better suited to sources where temperature variations are minimal or occur over a long period of time. Density changes (gas temperature changes) will influence the fan motor horsepower use. Cooler gas stream density causes an increase in the required fan motor horsepower to move a cubic foot of gas. Thus, comparisons of fan motor current must be normalized to some reference temperature and wide variation in temperature can make visual "quick checks" difficult.

Fan motor parameters provide confirming data when combined with fabric filter pressure drop. Data on fan motor current should be obtained whenever pressure drop is recorded. Plant personnel can use the combined data to determine the degree of bag blinding or the presence of pinhole leaks, tears, or excessive gas flow.

Parameter: Dust removal system operating checklist

Applicability: All systems except venting bins or silos

Method of Measurement: Visual

Limitations: None

Fabric filters not returning captured dust directly to a bin or silo are usually equipped with hoppers that need some method of removing the captured dust from the fabric filter. Unless equipped with manual dust removal, the dust discharge system should be checked periodically to confirm the operation of the system. Because it is generally recommended that dust discharge systems be operated on a continuous basis, finding items such as stopped conveyors or airlocks on the dust discharge will usually indicate that there is some sort of problem. Some plants avoid the problem of not noticing a failure of the dust discharge system by interlocking it with fan operation.

In most cases, a visual check every 1 to 2 hours is all that is needed (minimum of once per shift). A periodic check of the quantity of dust being removed from the fabric filter, however, is helpful as any gross variation from normal quantitites would indicate problems. Alternative methods of evaluating performance would include weighing material discharged or measuring the conveyor drive motor current.

4.2 MAINTENANCE RECORDS

Type of Record: Bag replacement

Applicability: All sources

One of the most telling indicators of proper operation and maintenance of a fabric filter is in the number of bags replaced and the average bag life. Most bags are designed to give 2 to 3 years of service before replacement is contemplated. The actual life will vary depending on service conditions. For each complete bag change, however, there should be a graphical chart to show the location and type of bag failure as shown in Figure 2.

There are various approaches to keeping bag failure records depending on the size of the fabric filter and the number of failures that occur. For larger multicompartmented fabric filters, the record may be kept by compartment to keep the diagrams manageable and/or by month if there are a significant number of failures. For most installations, however, a diagram for the entire fabric filter is practical and can, at a glance, help identify if a design or operating problem is occurring. Although a narrative can explain which bag was replaced, it is usually easier to show graphically where the bag was damaged and the date of the failure.

Parameter: Cleaning system operating checklist

Applicability: All installations

Method of Measurement: Pressure gauge (pulse-jet), magnehelic or manometer (shaker and reverse-air)

Limitations: None

The operation of the fabric filter cleaning system is one of the most overlooked items observed today. Although the bags may be in place and physically intact, many times the cleaning system will not be operating. Generally, a failure in the cleaning system will result in an excessive

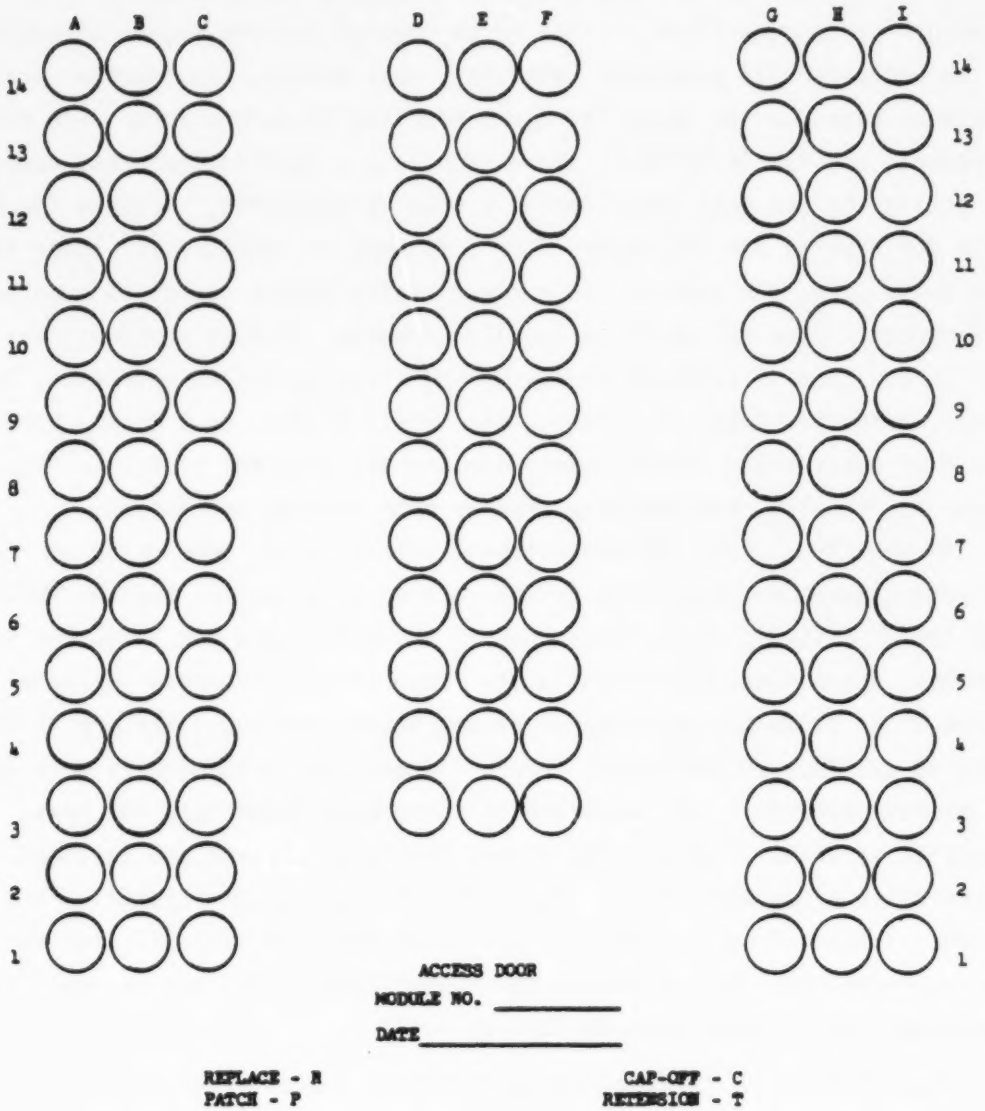

Figure 2. Bag failure location chart.

pressure drop across the fabric filter. A source that fails to monitor pressure drop, however, may not be aware of a failure in the cleaning system unless its operations are routinely checked or plant personnel notice that the exhaust gas stream is not being adequately removed because of the increased resistance.

Pulse-jet fabric filters should be checked every 24 hours at a minimum to ensure proper operation. Items to be checked include proper solenoid firing and pulse air pressure. Misfires, weak pulses, and improper pressure should be noted on the checklist for scheduling of maintenance. For shaker or reverse air fabric filters, there should be a confirmation that dampers are activating and that the cleaning system is operating. Because the A/C ratio for reverse air and shaker fabric filters is considerably lower than most pulse-jets, the need to check the cleaning system operation need not be as frequent. Once per shift is usually adequate for most applications.

In addition to external checks of the cleaning system operation, internal checks of shaker and reverse-air fabric filters on a weekly basis should be considered. Check points include the presence of fallen bags, proper bag tension, and adequate shaking from shaking mechanisms.

An additional note for those fabric filters using compressed air to activate dampers on shaker and reverse air or to clean the bags on pulse-jet type fabric filters; water and/or oil in the compressed air lines can cause problems. In winter, sufficiently low temperatures can cause the water to freeze or an oil/water emulsion to become sticky causing a failure in the cleaning system. For pulse-jet fabric filters, the situation is more damaging because water/oil can cause bag blinding when blown into the bags. The water/oil separators and airline dryers should be checked and serviced periodically along with the compressor(s) as they may be physically separated at some distance from the fabric filter. In addition, the oil that may be in the compressed airline can attack the rubber components such as seals and diaphragms, which cause them to fail as well.

Type of Record: Cleaning system and dust removal components
Applicability: All sources

In addition to the bags, the maintenance on the cleaning and dust removal system is an important indicator of performance. The information to be

recorded includes components replaced, reason for replacement, and date. This may be recorded in a maintenance log or by using a work order system. Excessive repairs may indicate the need for changing the design, operating mode, or inspection and maintenance schedule.

SECTION 5

VENTURI SCRUBBERS

There are numerous scrubber designs for removal of particulate matter and gaseous emissions. The most commonly employed scrubber for the control of particulate matter emissions is the venturi scrubber. Even within the classification of venturi scrubber there are several different design types: circular throats, rectangular throats, and fixed and variable throat designs. Although there are a number of different designs, the basic operating principles remain the same.

The goal of the venturi scrubber is to capture the particulate matter on water droplets that are easier to collect and remove. The particulate matter is usually much smaller than the water droplets. The mean particle size for particulate matter might be 5 to 10 microns, whereas water droplets may be 25 to 200 microns. The water droplets are usually easily separated in a cyclonic separator following the scrubber. The gas stream approaches the scrubber throat and accelerates to maximum speed (5,000 to 15,000 cm/s) as the cross-sectional area is reduced. Water is introduced at the scrubber throat where it is atomized by the gas stream (water can be introduced by spray nozzles, which form droplets that can be further atomized). The high relative velocity of the particulate matter compared to the water droplets causes the particulate matter to impact the droplets. This mechanism works well for particles above 2 microns. For particles less than 0.1 micron a diffusion mechanism predominates to remove very fine particles. Between 0.1 and 2 microns neither collection mechanism works well and collection efficiency is worst in this range. In general, more energy means greater collection efficiency as more water is accelerated to higher speeds, which results in greater pressure drops.

Venturi scrubbers can also collect gaseous pollutants simultaneously because intimate mixing between the gas and scrubber liquor occurs at the throat. There are other designs more suitable for collection of gaseous

compounds alone, but in some circumstances where particulate matter can present pluggage and fouling problems in packed-bed scrubbers, a venturi scrubber with its nonfouling characteristics may be more satisfactory. One example of a venturi scrubber used for gaseous emission control is in the sulfite pulping industry where recovery boilers burning magnesium-based, spent sulfite liquor use three or four venturi scrubbers in series to capture and reuse sulfur dioxide (SO_2) from the gas stream. Through careful control of pH, these scrubber trains can be quite effective in removing SO_2 from the gas stream.

A number of parameters are available to monitor scrubber performance and some are even used to control scrubber operation. The records associated with these operating and maintenance parameters include:

- Operating

  Pressure Drop
  Water Flow Rates (Recirculation, Make-Up, and Blowdown)
  pH
  Temperature
  Solids Content of Recirculated Scrubber Water
  Solids Removal from Settling Tanks or Ponds
  Fan Motor Current

- Maintenance

  Nozzle Replacement
  Throat Replacement or Adjustments
  Pump Impeller Wear

Opacity is not an operating parameter to be routinely monitored because wet plume characteristics typically interfere with proper transmissometer operation. Although some work has been done to develop a method of monitoring opacity in wet plumes, its application is not currently widespread and testing is still being performed to determine the acceptability of the data.

5.1 OPERATING RECORDS

Parameter: Pressure drop
Method of Measurement: Manometer, magnehelic, continuous chart recorder
Applicability: All sources
Limitations: Pluggage of taps and water in pressure sensing lines

One of the most useful operating parameters to be monitored in a venturi scrubber is pressure drop. The pressure drop should be monitored across the throat of the venturi scrubber and not across the entire scrubber train (presaturator, scrubber, and separator) for the most useful information. Pressure drop is the parameter monitored and used to control the operation of variable throat scrubbers (opening and closing the throat as needed with constant water flow rate). It is also one of the first parameters available to indicate problems in scrubber operation.

Smaller sources using low pressure drop scrubbers probably only need to have pressure drop indicated in a control room where operators can periodically record the values in the daily logs (i.e., once every two or three hours as a minimum). Larger sources should consider continuous chart recorders. Sources with little fluctuation in operating charactristics and/or variable throat scrubbers with automatic controls should see only small changes in pressure drop. Sources with variable process rates and fixed throat scrubbers will likely observe greater fluctuation in pressure drop.

Parameter: Water flow rates

Method of Measurement: Orifice or venturi meters, rotameters, ultrasonic meters, pump motor current

Applicability: All sources

Limitations: Pluggage or miscalibration of meters, high solids can cause problems in all but noncontact devices

The second most useful parameter in monitoring scrubber operation is water flow rate. Unfortunately, it is rarely monitored except at the largest sources. The difficulty usually lies in the equipment used to monitor flow. Orifice and venturi meters are subject to wear and buildup from suspended solids in the water that changes meter calibration. The same problem can occur in rotameters as well as turbidity problems making reading of the meter very difficult because one must read a floating bob position against a calibrated sight glass. Ultrasonic meters are usually noncontact devices and are not subject to the wear problems associated with the other meters mentioned. The ultrasonic meters, however, are very expensive and generally do not handle shocks well, which means that these devices must be handled carefully during installation. In addition, special maintenance is required. Another alternative is to monitor pump motor current to indirectly monitor flow. But

on all but the largest pumps the horsepower requirements are low and subtle differences between power input may be difficult to distinguish.

Given the problems and costs associated with the monitoring of scrubber water flow rates, sources will often opt to measure or monitor water supply pressure to the scrubber. Although this indicates the header is pressurized, it does not provide an indication of water flow rate through the pipe. Water pressure is not an adequate substitute for water flow rate.

In addition to scrubber flow rate, the makeup to and/or blowdown rates of water from the scrubber system should also be monitored. This is important to the solids buildup rate and amount of evaporative losses in the scrubber. Flow monitor outputs should be available to operators and if not measured and recorded continuously then data should be recorded at a minimum of once every 2 hours. Water flow rate to the scrubber is typically not varied (the exception is some fixed throat scrubbers that vary flow rate to control pressure drop) although makeup or blowdown may vary. A QA program including routine calibration of flow meters should be required (usually once per month).

Parameter: pH
Method of Measurement: pH meter or monitor
Applicability: Limited
Limitations: pH sensors prone to pluggage and failure

Monitoring scrubber water pH is rarely needed in many of todays scrubber applications. The use of pH monitoring is typically limited to carbon steel scrubbers that are susceptible to acid attack and to applications where gaseous emission control is part of the scrubbers function. The pH monitor helps operators maintain the proper pH to limit corrosion or to operate in the most effective absorption range for the scrubber.

Generally, pH monitors have required a substantial amount of maintenance to remain operational. Most successful applications of pH meters for continuous pH monitoring employ sidestream monitors where only a small of the flow is monitored rather than the total water flow through the scrubber.

Parameter: Gas temperature
Method of Measurement: Thermocouple
Applicability: All high temperature sources

Limitations: None

Temperature of the gas stream both before and after the scrubber are important indicators for scrubber operation. Saturated gas conditions represented by gas temperatures in the 150° to 160°F range should be expected as a result of evaporative cooling by the scrubber. Water loss by evaporative cooling may account for 5 to 10 percent of the total water flow in high temperature application. This may cause an increase in emission rate if the solids levels are high in the scrubber water.

The inlet temperature is useful for indicating the need for a cooler/presaturator ahead of the scrubber. High temperature gas streams may contain components that are gaseous until cooled in the scrubber. These materials may form in particle size ranges that are difficult to capture. In addition, the outlet temperature can be used to determine if saturated conditions are being achieved. Temperatures higher than saturation usually indicate maldistribution of gas and/or water within the scrubber.

Temperatures should be monitored periodically (once every 2 hours minimum) for relatively steady-state source. Sources that vary considerably in operation should consider continuous chart recorders to record temperature data.

Parameter: Solids content of scrubber water
Method of Measurement: Water sample, balance
Applicability: High temperature sources
Limitations: None

A frequent problem observed is the resuspension and regeneration of particulate matter into the gas stream because the solids levels are too high for the particular application. Resuspension generally refers to suspended solids in the scrubber water that are suspended once the water is evaporated away from the particles. Regeneration generally refers to the particle formation that occurs from dissolved solids and salts when water is evaporated. Typically regenerated particulate forms a very fine, very difficult to collect fume.

Periodic samples should be collected, particularly at sources where little blowdown of scrubber water occurs. Buildups of 5 to 10 percent dissolved solids can occur and cause significant problems with plume opacity and

in some cases, erosion of scrubber components. Weekly grab samples should be considered minimum for sampling from the scrubber sump return. If water with high dissolved and suspended solids are used in a presaturator, high residual opacity may occur. The level of dissolved and suspended solids that can be tolerated will be very site specific.

Parameter: Solids removal
Applicability: All scrubbers with settling ponds
Method of Measurement: None
Limitation: None

Part of the operation of a scrubber involves the settling and removal of solids captured by the water droplets. Although automatic clarifier systems do exist, most scrubbers use settling ponds that have to be emptied manually (usually draining and removing sludge with a front-end loader). Each time the pond is cleaned it should be noted in the operating records to establish representative operation. In this way the representativeness of a stack test may be determined if the scrubber was operated with clean water and a clean settling pond.

5.2 MAINTENANCE RECORDS

With few moving parts, the required maintenance records for a scrubber are not extensive.

Maintenance Parameter: Nozzle Replacement
Applicability: All scrubbers equipped with nozzles
Limitations: None

New scrubber designs consider nozzle accessibility and ease of replacement for maintenance personnel. Consequently in many applications, nozzle replacement can be accomplished while the scrubber is on-line. Nozzle replacements should be part of the maintenance records including the reason the nozzle was replaced (i.e., erosion, pluggage, preventive maintenance, etc.). In addition, a routine check of the nozzle operation should be included as part of a preventive maintenance plan. A minimum of once per week is necessary although once per day would be preferable.

Maintenance Parameter: Throat adjustments or replacement

Applicability: All scrubbers

Limitations: None

Adjustments to the scrubber throat or to the controls of a variable throat scrubber should be maintained in the maintenance records. Without this information sudden changes in performance are not easily explained. An example of this was found at a grey-iron foundry when extreme erosion of the scrubber throat forced maintenance personnel to patch the scrubber with a steel plate. After applying several layers of steel patches, the configuration of the scrubber (inside) was considerably different, which severely reduced the draft on the blast furnace causing excessive fugitive emissions. As a result, maintenance personnel would go to repair another patch and decide to replace all the previous repairs and duct again. This repair would always return the scrubber to near initial design and performance would be restored until the next major repair 3 to 4 months later after performance progressively got worse. No records of maintenance were kept so that it was merely by accident that the cause of the variable performance was discovered. Pressure drop and water flow rate seemed normal during the time that performance grew worse. However, if records of what had been done had been kept, the solution would have been easier to identify.

Maintenance parameters: Pump impeller wear

Applicability: All scrubbers

Limitations: None

Pump impellers should be checked periodically for wear. The greater the suspended solids content of the scrubber solution, the greater the chance for pump impeller wear. As the pump wears, the ability to pump a given quantity of water at a fixed pressure decreases. This affects both water volume capacity to the scrubber and delivery pressure to the scrubber (nozzle designs may generate different drop sizes with different pressure characteristics). Each time the pump housing is opened and checked or the impeller is replaced it should be noted in the maintenance record.

SECTION 6

ELECTROSTATIC PRECIPITATORS

The ESP is probably the most complicated of the control equipment types discussed in this manual. Although the operating principles are relatively straightforward there are a large number of parameters to be specified and most designs are a compromise between the various factors to arrive at an economical yet reliable control device. To adequately monitor ESP performance, however, there are a large number of parameters that should be monitored. Unfortunately this can require a substantial investment in personnel to obtain and/or correlate the information recorded. Thus, on a generously designed and reliable ESP there may be justification for reducing the amount of data obtained or, at least, the amount of daily data reduction.

Unlike other types of control equipment discussed in this manual, the energy expended in collecting particulate matter is applied directly to the particulate matter and not to the entire gas stream. Consequently, pressure drop through an ESP is not an indicator or even a factor to be considered during normal operation. The electrical energy used goes to creating a corona discharge, charging of particles, moving the particles across the gas stream to the collection plates, and partially discharging the particles while retaining them on the plates until they are ultimately removed from the ESP. The operation of the ESP may seem very complex and, indeed, it can be. But the main indicators of ESP performance are closely related to the trends of the voltage and current characteristics within the ESP. In fact if more time was taken evaluating the voltage/current readings of the ESP, many sources could probably function quite well taking and analyzing only the electrical readings and opacity values to determine if an ESP is functioning properly. There are, however, many other parameters that can be calculated for ESP performance as well as many items that should be periodically checked. Briefly, these items are:

Operating Records

Voltage and current readings
Opacity
Gas temperature
Gas composition
Gas volume
Conditioning agents addition
Gas load V-I curves (supplemental)
Resistivity tests (supplemental)
Carbon loss or loss-on-ignition (LOI) tests
Rapper operation checklist
Transformer-rectifer (T-R) set checklist
Hopper heater and dust discharge checklist
Insulator heater checklist

Maintenance Records

Wire breakage, removal, and replacement diagram
Rapper replacement diagram
T-R repair/replacement
Insulator/heater replacement
Dust discharge system repair
Misalignment
Air load V-I curves
Gas flow distribution tests (supplemental)

As can be seen the list is very extensive and can extend even further when one considers the process data that can also be recorded. Because ESP's are generally sensitive to variation in process operating conditions or other factors (e.g., sulfur content in coal burned at a boiler and its effect on ash resistivity) process data and evaluation of their effects on ESP operation are particularly important. Arguably each of these records can be viewed as necessary to diagnosing the performance of an ESP or troubleshooting if problems are noted. There are sources that integrate each and every one of these elements into their overall preventive maintenance program. The key, however, is not the amount of data created but what is done with it

particularly in fine tuning operations or minimizing problems once discovered. Some items will be listed as "optional" although the arguments for including that element into the recordkeeping program will be strong. Only site-specific consideration will help determine what elements are truly needed.

6.1 OPERATING RECORDS

Parameter: Voltage and current readings

Applicability: All sources

Measurement method: Voltage and current meters for each T-R control

Limitations: Meters may provide an indirect measurement of the individual parameter to be recorded. Require periodic recalibration. Small positive corona two-stage ESP's may not be equipped with meters

The most important parameters that should be recorded for an operating ESP are the voltage and current values for each T-R set. The individual values for each T-R voltage and current are important but more important are the trends noted within the ESP. The most notable trend is the increase in current density and power density in the various fields as the gas moves from inlet to outlet.

There can be a significant variation in the operating values for an ESP and changes sometimes occur within minutes. Variations caused by gas volume and temperature, particulate matter characteristics and even the depth of buildup of dust on the plates can all play an important role in changing the values of voltage and current. But these readings also provide the first warnings of problems within the ESP.

The readings should be taken at least once every 8 hours during normal operation although once every 4 hours may be preferable for giving more advanced warning of problems. The values for primary voltage and current as well as secondary voltage and current should be recorded where available. For small ESP's this produces only a small quantity of data. For large systems, application of digital based data loggers may be required. In all situations, the values should be compared against a baseline or "normal" value to determine if significant variations are occurring and if further action should be taken.

Parameter: Opacity

Applicability: Most larger and moderate sized sources

Measurement Method: Double-pass transmissometer

Limitations: Variations in particulate characteristics (particle size) may limit usefulness. Six-minute integration smooths out spikes in data that may be useful in optimizing ESP performance. Siting criteria must be met

In many situations, ESP operation is usually evaluated in terms of the opacity observed by a transmissometer on a real-time basis. Under optimum conditions the ESP should be capable of operating at some "constant" or base opacity with a minimum amount of spiking from rapper reentrainment. These data can also be supplied to an integrator to provide 6-minute averages to fulfill regulatory requirements. Some sources are capable of providing both data. Provisions should be available to provide the real-time data for plant or agency personnel to evaluate the degree of spiking that occurs and any significant changes in operation. (Note: Some methods of integrating can potential miss the problems associated with spiking although they will show a higher than "base" opacity.)

Many sources rely on the opacity meter as being the first indicator of problems and this is useful as long as the opacity versus mass relationship does not vary significantly with operating conditions. When used with electrical readings the opacity measure can be very reliable. In those cases, however, where extreme changes in particle characteristics may occur (e.g., poor combustion of fuel in a boiler, some kraft recovery furnaces, alkalies in cement production), these mass concentrations may change by an order of magnitude without changing opacity. Sometimes opacity can change without a corresponding change in emission rate (concentration). These, however, tend to be the exception although both agency and plant personnel need to be aware that such changes can occur.

Some sources have tried to correlate ESP power readings with emission rate and/or opacity. At the midpoint of the range of power levels there may be good correlation with the relationship deteriorating at very high and very low power readings. The opacity reading used is usually the 6-minute average at the time of the readings. Over a long period of time there may be strong correlation, but for any given set of readings there may be no apparent relationship between opacity and power input.

Parameter: Gas temperature

Applicability: All sources

Measurement Method: Thermocouples, thermometers

Limitations: Stratification in duct and representative values

Changes in gas temperature can have profound effects on ESP performance. The temperature variation can be very small and yet cause a significant change in ESP power levels and opacity (in some cases as little as 15°F). Although gas temperature variations may have some effect on corona discharge characteristics and physical characteristics of the ESP (corrosion, expansion/contraction), its most important effect is on particle resistivity. For sources with the potential for high resistivity, the change in performance can be dramatic as a result of temperature changes when all other parameters seem to be the same. The gas temperature should be checked once per shift for smaller sources and measured continuously on larger sources and on those sources with temperature sensitive performance.

Temperature measurement can also be a useful tool in finding excessive inleakage or an unequal flow through the ESP. These can affect localized velocity patterns within the ESP which, while the average value seems adequate, can cause reduced performance within the ESP. Most ESPs are designed with a minimum of two chambers. The gas temperature for each chamber should be measured at both the inlet and outlet, if possible. Significant temperature changes between the inlet and outlet values may indicate inleakage problems that should be confirmed by measurement of gas composition. A single point temperature probe may miss stratification within the duct and the duct should be checked periodically to assess the degree of stratification and determine the representativeness of the selected measurement location.

Parameter: Gas composition

Applicability: Source dependent, optional

Measurement Method: Continuous monitor for appropriate pollutant(s) or gases

Limitations: Some monitors used for protection from explosions give limited protection. Stratification considerations are important

Continuous monitors are often required to fulfill regulatory requirements. In some cases, however, monitors are placed to prevent or reduce the chances of explosions within the ESP. The most common example is the use of hydrocarbon and/or CO monitors on cement plant applications.

A useful monitor on combustion sources is a continuous oxygen analyzer usually placed at the inlet of the ESP but may be colocated with another monitor. The oxygen analyzer can be useful in determining the amount of excess air that is brought into the ESP along with other combustion products, although not particular useful for process control. If continuous monitors are not available, usually a weekly grab measurement of oxygen with ORSAT or Fyrite analyses are sufficient. It should be noted that stratification in the ductwork can present measurement problems.

Parameter: Gas volume
Applicability: Optional, sources with "marginal" design parameters
Measurement Method: Pitot tube, F-factor, fan current and speed
Limitations: Can be time consuming to obtain and reduce data

Gas volume is important to ESP operation because most of the key design and operating parameters such as specific collection area (ft^2/1000 acfm), superficial velocity, treatment time, and specific corona power (watts/1000 acfm) are dependent on gas volume. Routine gas volume calculations are recommended for those designs and operating practices that do not provide an adequate margin for operation. For example, significant variations in oxygen may indicate large swings in the gas volume that may decrease ESP performance and indicate the need to routinely determine ESP gas volume. Low SCA values, high superficial velocities (6 ft/s), short gas treatment times (5 s or less), and much higher oxygen levels at near full load conditions are indicators that would suggest that excess gas volume may be decreasing ESP performance.

Parameter: Conditioning agent addition
Applicability: Units equipped with gas conditioning equipment
Measurement Method: Various
Limitations: Periodic calibration

Conditioning agents are usually added to the gas stream to modify resistivity of the particulate matter entering the ESP. Conditioning agents

may include water (dry process cement plants), SO_3 and H_2SO_4 (coal-fired boilers with low-sulfur coal), and even the addition of sodium compounds to the coal for some boilers. Feed rates should be monitored for changes relative to the ash production rate. In addition, access to nozzles for periodic maintenance checks should be provided for water and sulfur based conditioning systems to prevent pluggage problems.

Parameter: Gas load V-I curves

Applicability: As needed

Method of Measurement: Voltage/current meters on T-R controls

Limitations: May vary due to internal ESP factors

Gas load voltage-current curves (also known as V-I curves) are usually performed on fields where problems are suspected although in rare cases the entire ESP may be checked. The curves can be useful in diagnosing alignment problems, dust buildup problems, changes in resistivity, insulator tracking problems, and some T-R controller problems. When more than one field is being checked the outlet fields should be checked by first moving forward towards the inlet. This minimizes interferences within the ESP while the field is deenergized to establish the corona initiation voltage. It may be difficult to compare V-I curves from day-to-day or even with air load conditions. The gas load V-I curves, however, should become part of voltage/current records for diagnostic purposes.

There are some cases where the V-I curves are used to establish the optimum level for collection of high resistivity dust because the controllers are unable to "recognize" high resistivity. In this situation, the controls are usually left in the manual mode and it is generally unnecessary to show these curves developed for each period before readjustment.

Parameter: Resistivity

Applicability: As needed

Measurement Method: In-situ resistivity probe, bulk sample (external)

Limitations: Difficulties in measurement and differences in two methods may not show agreement in resistivity

Particulate matter resistivity tests are usually performed when other possible reasons for poor performance have been eliminated. Two methods are

generally used: in-situ and external bulk sample. The methods differ significantly and can produce drastically different results.

. The in-situ method measures voltage and current under clean probe conditions and the electrostatically collected particles on a sample plate where the "dirty" voltage/current values are generated. The test is usually conducted at the inlet of the ESP. The advantage of this system is that the sample is measured under action operating conditions for temperature, moisture, gas composition, and particle characteristics. The disadvantage of the method is that it is often difficult to measure the thickness of the dust layer and the resistivity is measured only under actual gas conditions with no real ability to modify them.

The bulk external method usually aspirates a sample out of the ESP inlet. In the lab it is fused in a crucible at approximately 800°C and then placed on a plate and subjected to various gas conditions to generate a resistivity profile. The advantage of this system is that sample thickness can be more easily controlled and gas conditions can be varied both for temperature and for gas components. The disadvantage is that the action of fusing the sample may volatize or oxidize resistivity modifiers that under actual operating conditions assist ESP performance. Generally, the two methods will not agree precisely although each has its advantages and disadvantages. The results of such analyses should be kept as part of the operating record.

Parameter: Carbon loss or loss on ignition (LOI)

Applicability: Fossil fuel fired utilities, or any sources where carbon in the ash can be substantial. Optional

Measurement Method: ASTM method

Limitations: None

The LOI tests are routinely conducted at some utilities as a method of tracking combustion performance. This periodic measurement is usually carried out daily or weekly. Carbon in the sample can act as an effective resistivity modifier in some cases. Generally, the improvement in resistivity can be seen in levels up to 10 to 12 percent carbon in the ash. The economics of carbon loss, however, may force these levels to remain low. Below 1.5 to 2.0 percent carbon in the ash, the carbon generally does not modify resistivity. Extremely high levels of carbon in the fly ash can lead

to extremely poor ESP performance as well as increase the potential for fires and explosions. High levels usually indicate the need for burner adjustment.

Parameter: Operation checklists for rappers, T-R's, hopper heaters, dust discharge, and insulator heaters

Applicability: All sources

Method of Measurement: Various

Limitations: Access to some items

In addition to the daily monitoring of data some operation checkpoints should be included. These include a once per shift check of rapper operation, dust discharge system, and T-R set operation (indicating the ones in the "off" position). Rappers not functioning should be scheduled for maintenance particularly if large sections of rappers are out of service. Dust discharge systems should have highest priority for repair as dust should not accumulate in the bottom of the ESP for long periods of time because of the potential for causing severe plate misalignment problems. Hopper heaters can usually be repaired with little difficulty after removing weather protection and insulation. Insulator heaters may be difficult to repair except during short outages. These heaters are important to keep condensation on the insulators to a minimum although hopper heaters generally help keep the dust warm and free flowing. As each shift data sheet and checklist are completed, they should be evaluated for maintenance needs.

6.2 MAINTENANCE RECORDS

The work order system for prioritizing, dispatching, and providing written information on what conditions were found and what repairs were made seems particularly well adopted to an ESP where a large number of records may be necessary for retrieval. There may have to be supplemental files, however, for such items as internal inspection reports, air-load V-I curves, and wire replacement charts for ESP maintenance. Although the log book concept may still be used, on large ESP's the "routine" maintenance reporting is much more important.

Type of Record: Wire replacement chart

Applicability: All ESP's equipped with wires

Although an ESP can operate effectively with up to 10 percent of its wires removed, care must be taken that no more than 5 to 10 wires in any one gas lane are removed. The loss of wires down any one lane can result in a substantial increase in emissions. The only way to adequately track where wires have failed and been clipped out of the ESP is with a wire replacement chart. In general, a few wire breaks randomly distributed can be expected after installation, with few during normal operation and then more frequent occurrences of breakage at the end of wire life. Many factors influence wire performance including sparking, alignment, corrosion, and even construction and installation practices.

It is not unusual for wires to be simply removed and not replaced if they break. The wire location and the location of the break (top, middle, bottom) should be noted. If wires are replaced, this should also be noted.

Wire breakage can keep a substantial portion of the ESP deenergized even if there is only one wire break in each section deenergized. The wire breakage chart can help maintenance personnel determine if patterns are random or more concentrated in a given area.

Type of Record: Rapper replacement/repair
Applicability: ESP's equipped with rappers

With the exception of wet ESP's, all other ESP's use rappers to remove dust buildup on the collection plates and the discharge electrodes. For the rigid-frame and rigid-electrode type ESP's, checks and replacement of the rapping system components is usually limited to periods when the ESP is deenergized and open for access. Only the drive and the gear reduction mechanisms are available outside the ESP for maintenance. On weighted-wire ESP's, however, the rappers are usually external and more easily checked.

Rappers should be checked each shift for operation. This check may only be cursory to determine if the rapper system is functioning. Once each week, however, the rappers should be more carefully checked to determine which, if any, rappers need repair or replacement. This check also extends to the rapper control system. The failure of an individual rapper or two will probably have little effect on overall ESP performance. But the loss of an entire section of rappers or the rappers on an entire ESP can be more severe. The type of repair should be noted to see if a pattern exists. For example,

on one ESP the number of coil burn-outs and failure of rapper control cards suggested high voltage was somehow feeding back through the system. Grounding the rappers and supplying the system with diodes eliminated the problem but it took several years to accumulate enough data to realize a repeating pattern was occurring.

In addition, any adjustment to the rapping frequency and intensity should be noted. Very often, this is an easy item to be changed when things seem not to be working and when the values are changed without any notification, it is extremely difficult to restore the rapping intensity and/or frequency back to their original, perhaps more optional, levels.

Type of Record: T-R problems
Applicability: All ESP's

Generally, the number of T-R problems is small. Failure of controllers, changes in allowable spark rate, current limit, and replacement of meters, however, should be noted in this file. Also, changes in the normal wiring arrangement of the ESP should also be noted. In some applications it is not uncommon to rewire or "jumper" the ESP so that additional sections of the ESP may be energized when a T-R failure occurs. It is not always possible to determine this from T-R meter readings and if this practice occurs, diagrams or listings of what T-R energizes what section should be maintained so that future analyses of the operating data can be adequately conducted.

Type of Record: Insulator heater/hopper heater replacement
Applicability: Optional

Insulator heater failures and replacement may correlate with the need to replace insulators because of excessive tracking. For most sources, however, the problem is not severe and separate records are not necessary. Hopper heaters may only be needed at certain times in some applications (startup, cold weather) and sometimes plugged hoppers can be traced in part to failure of hopper heaters. Again, this is a relatively minor problem and separate records are not necessary.

Type of Record: Dust discharge system repairs
Applicability: All ESP's

Each time there is a failure in the dust discharge system there is the potential for dust buildup to cause temporary problems (dust buildup between

plates, reduced power at increased sparking, grounding of portions of the ESP) as well as permanent problems (misalignment). Each time a failure occurs and is repaired, the cause of the problem (if found) should be noted and the electrical characteristics of the fields near the problem area should be checked after the repair to see if they return to normal levels using gas load V-I curves. The main concern is misalignment within the ESP. It is possible in some cases to trace misalignment within an ESP back to a specific incidence of hopper pluggage or failure of the dust removal system. This is one of the most common ways to misalign an ESP.

Type of Record: Misalignment and repairs
Applicability: All ESP's

The presence of misalignment of the ESP internals can often be detected through the electrical readings. The precise location of misalignment, however, can usually be determined only by an internal inspection of the ESP during a shutdown period. In some cases, the cause of the misalignment can be repaired and in others it may be impossible or impractical to repair. Misalignment can be caused by warped plates, shifting of support frames, broken insulators, and even structural failure of the ESP. The analysis of wire breakage records may indicate localized misalignment because those areas have greater occurrences of wire breakage. Misalignment most often causes localized areas of high sparking that may result in wire breakage. If misalignment can be repaired it will help reduce wire failures and increase operating voltages. If it cannot be repaired, other steps such as cutting out wires in the affected areas to increase operating voltages, reduce the effect of wire breakage, and keep the T-R's in service may be an acceptable alternative to reduced or no energization.

Type of Record: Air load V-I curves
Applicability: All ESP's

Initially, before startup, the ESP should be energized to establish if it is ready for operation. The voltage/current characteristics established under these conditions should become part of the permanent record for the ESP. After each shutdown when maintenance is performed, an air-load V-I curve should be produced that verifies that the ESP is ready for operation. In fact, before and after V-I curves (if possible) are a good idea to provide

evidence that problems were found and corrected. The patterns in a well aligned, well maintained ESP should be similar to the original V-I curves. If problems were not corrected, the air-load V-I curve provides evidence that further maintenance is required to find and isolate the problem(s).

Type of Record: Gas Flow Distribution
Applicability: Optional

Gas flow distribution problems are often blamed for a number of ESP performance problems but it is often difficult to prove because the testing methodology is cumbersome. A hot-wire anemometer test is usually conducted during shut down to demonstrate the presence of unsuitable gas flow distribution. This can be considered a special test for most ESP's as most flow orientation devices are installed within the ESP duct work on the basis of experience and flow model studies. If severe maldistribution is noted, then corrective actions should be scheduled. Repairs and modifications to the original design should be recorded. Hot-wire anemometer tests taken after the repairs or modifications have been made should also be kept to demonstrate problems have been corrected. Other ESP functions such as T-R set-points, rapper operation, and dust discharge system functions may have to be optimized to reflect the new operating conditions within the ESP. Because most ESP's are very sensitive to gas flow distribution problems, correction will usually result in improved performance.

6.3 SUMMARY

The listing of items to be recorded and tracked for ESP's is extensive even with the exclusion of items such as lubrication, routine filter changes, and process parameters. This is due, in part, to the sensitivity of ESP performance to a number of operating parameters and the operating principles of applying energy directly to remove particulate matter. There is also, however, more instrumentation available on most ESP's when compared to other control equipment that provides useful information about performance and the effects of changes of various operating parameters. As stated earlier, many sources find that a work order system works well with ESP maintenance because there are many items that must be addressed. On the operating data side, the manipulation of electrical data can become manpower intensive and typically

requires at least one person to become familiar with the operating characteristics to quickly analyze and evaluate performance characteristics. Properly designed, operated, and maintained, the ESP can provide high particulate matter removal efficiency to maintain continuous compliance with the applicable emission limits.

APPENDIX A

EXAMPLE WORK ORDER FORM

WORK ORDER

	FOSSIL STATION WORK REQUEST	ORIGINATOR	DATE	UNIT	PRIORITY	STATION	W. R. NO.
LOCATION - EQUIPMENT	AVAILABLE - DATE	REQ'D. COMP DATE	RED TAG YES / NO	APPROVED BY	DATE		EQUIP. NO.
EQUIPMENT NAME OR JOB TITLE				CHARGE TO:	PLANNER		CODE
DESCRIPTION OF JOB						TOOL LIST	CLASS

ESTIMATED LABOR DESCRIPTION OF WORK BY CRAFT SKILLS	SEQ.	CRAFT SKILL	MEN X HOURS	TOTAL ESTIMATED MAN/HOURS
SAFETY PROCEDURES:				
SAFETY EQUIPMENT REQUIRED:				
REMARKS:				

MATERIAL REQUIREMENT — DATE REQ'D. — DELIVER TO:

DESCRIPTION	STOCK NO.	QTY.	AVAIL.	USED
SPECIAL EQUIP REQUIRED				

ACCEPTED BY	DATE	MAINTENANCE SUPERVISOR	DATE	CODE

(Copyright © April 1983, EPRI Report CS-2908, "Proceedings: Conference on Electrostatic Precipitation Technology for Coal Fired Plants". Reprinted with permission.)

UNIT	SYSTEM	SUBSYSTEM	COMPONENT	SUBCOMPONENT

MAINTENANCE REQUEST FORM 000000

ORIGINATOR: _____ DATE: _____ TIME: _____

ASSIGNED TO:

1	MECH.
2	ELECT.
3	INSTR.

PRIORITY:

1	EMERGENCY
2	SAME DAY
3	ROUTINE

UNIT STATUS:

1	NORMAL
2	DERATED
3	DOWN

PROBLEM DESCRIPTION: _____

FOREMAN: _____ DATE: _____ JOB STATUS:

1	REPAIRABLE
2	HOLD FOR: TOOLS
3	PARTS
4	OUTAGE

CAUSE OF PROBLEM: _____

WORK DONE: _____

SUPERVISOR: _____ COMPLETION DATE: _____

MATERIALS USED: _____

TOTAL MANHOURS	MATERIAL COST

(Copyright © April 1983, EPRI Report CS-2908, "Proceedings: Conference on Electrostatic Precipitation Technology for Coal Fired Plants". Reprinted with permission.)

United States
Environmental Protection
Agency

Stationary Source Compliance Division
Office of Air Quality Planning and Standards
Washington DC 20460

Official Business
Penalty for Private Use
$300

B235
11

If your address is incorrect, please change on the above label; tear off; and return to the above address.
If you do not desire to continue receiving this technical report series, CHECK HERE ☐; tear off label; and return it to the above address.